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Effect of thickness on the piezoelectric properties of $LiNbO_3$ films

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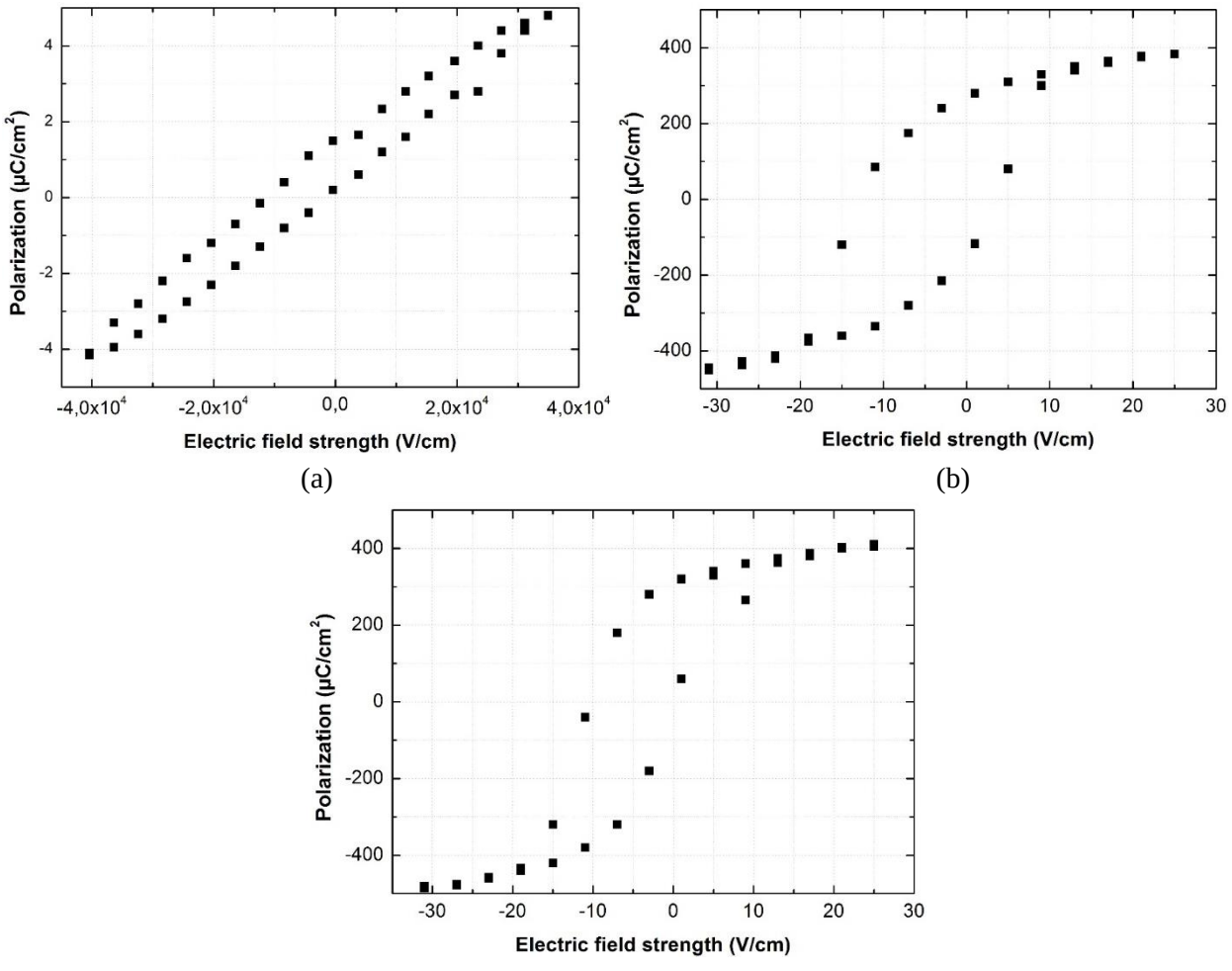
Currently, lithium niobate ($LiNbO_3$) is widely used with the development and manufacture of acousto-optical devices, optical phase modulators, waveguides, elements of non-volatile memory due to unique combination of its physical and optical properties [1]. Moreover, $LiNbO_3$ films are multicomponent oxides and their properties (crystallographic orientation, surface roughness, resistivity, concentration and mobility of charge carriers, optical and piezoelectric properties) depends on the stoichiometric composition and structure, which in turn depends on the method and formation conditions.

The formation of nanostructured $LiNbO_3$ films was carried out in multifunctional nanotechnology complex NANOFAB NTK-9 (NT-MDT, Moscow) comprising Pioneer 180 pulsed laser deposition module (Neocera Co., USA). The evaporation of $LiNbO_3$ target was carried out with KrF excimer laser (Coherent Inc., USA) (λ = 248 nm). The number of pulses varied from 50 000 to 200 000 at a repetition rate of 10 Hz. The oxygen pressure in the growth chamber was 10^{-2} Torr.

Figure 1 shows the dependences of the polarization on the magnitude of electric field strength for $LiNbO_3$ films with different thicknesses.



(a) (b)

(c)

Figure 1. Dependence of the polarization on the field strength for samples with different thicknesses: (a) 47.5 nm, (b) 110.1 nm, (c) 143.8 nm.

With increasing of film thickness from 110.1 to 143.8 nm, the dependences of polarization on the field strength were hysteresis (Fig. 1a,b). This fact characterizes the films as ferroelectric. An analogous dependence for the sample with 47.5 nm film thickness has the shape of an ellipse (Fig. 1c). The obtained dependences characterize the samples, with a thickness of 110.1 - 143.8 nm, as films with spontaneous polarization, whereas the sample with thickness of 47.5 nm has relaxation character of polarization. Moreover, it is established that increasing charge carriers mobility from 75.553 to 131.033 $cm^2/V \cdot s$ results in decreasing in the value of the residual polarization from 322 to 243 $\mu C/cm^2$. Changing in the charge carriers concentration from $7.325 \cdot 10^{17}$ to $3.24 \cdot 10^{19}$ cm^{-3}, leads to the value of the dielectric loss tangent increases from 0.35 to 70. With the further increasing in the concentration to $7.918 \cdot 10^{19}$ cm^{-3}, the dielectric loss tangent decreases to 5.6. Obtained results could be used in the developing and manufacturing of integrated acousto-optical devices and sensors based on surface acoustic waves.

The results were obtained using the equipment of Research and Education Center and the Center of collective use "Nanotechnology" of Southern Federal University.

1. J. Piprek, *Handbook of Optoelectronic Device Modeling and Simulation: Fundamentals, Materials, Nanostructures, LEDs, and Amplifiers* (CRC Press), 814 (2017).